Acoustic Directivity of the DGEN Aero-propulsion Research Turbofan at Multiple Farfield Array Locations

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AIAA Aviation Forum

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National Aeronautics and Space Administration
Aeronautics Research Mission Directorate
Advanced Air Vehicles Program
Advanced Air Transportation Technology Project
Aircraft Noise Reduction Technical Challenge

OUTLINE

I) DART Overview

II) Baseline Data
- a) Spectral Content
- b) Repeatability

III) Symmetry
- a) Circular Array
- b) Linear Array

IV) Conclusion

I) DART Overview

DGEN380 Turbofan Engine

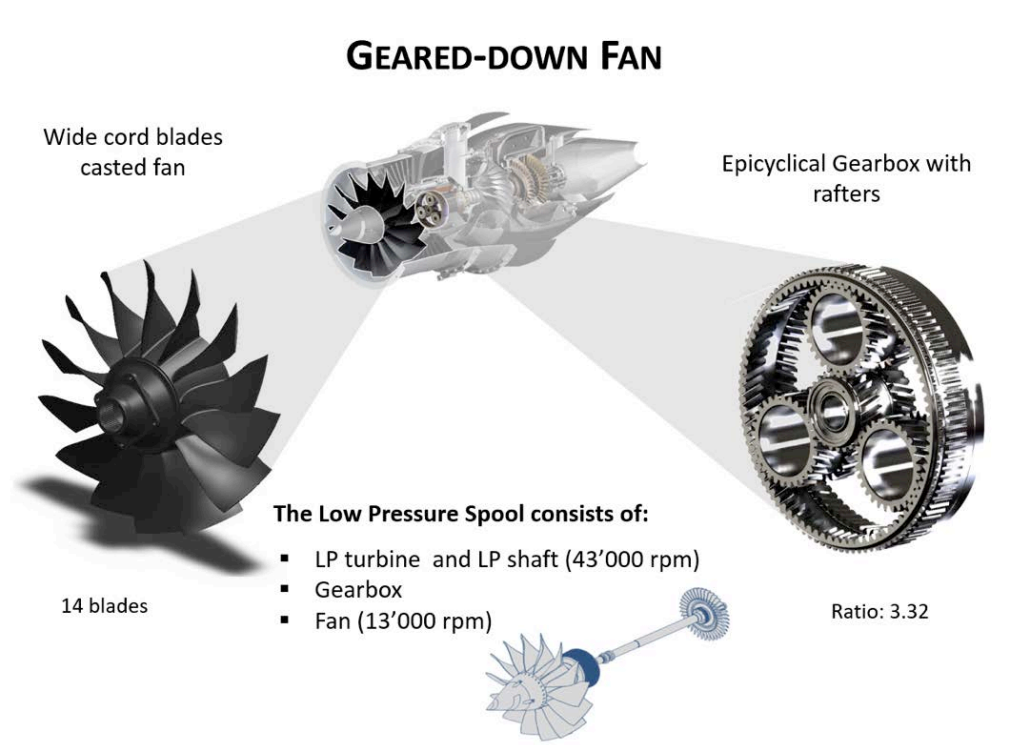
2 spool, geared fan (3.32 ratio), unmixed, separate flow exhaust

Centrifugal compressor, LP turbine (43,000 rpm), HP turbine (52,000 rpm)

14 inch diameter fan, 14 fan blades (13,000 rpm)

Thrust 560 lbf, 7.6 BPR,1.2 FPR, 5.3 OPR, 28.7 lb/s

Inlet mass flow, V_{tip} = 785 fps subsonic tip speed



Low component count/easy disassembly
Drawings Available

Background

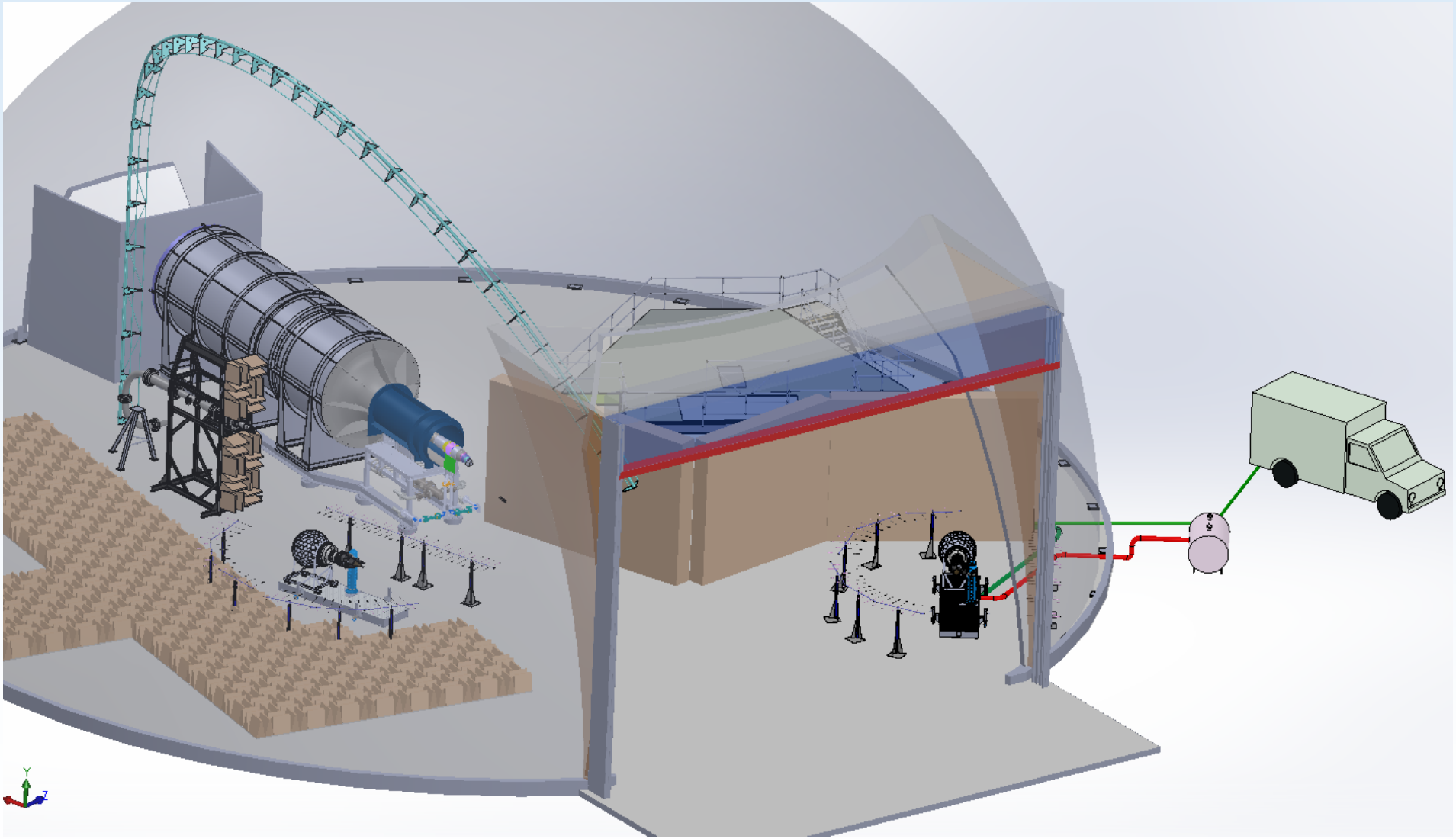
April 2017 DART entry at “ANCF” location provided installation checkouts and baseline acoustic/performance data.

A 2nd entry occurred to accomplish several goals:

1) Operate DART in center location (relocated cabling/fuel, etc)
2) Evaluate an existing noise reduction technology.
   Limited time frame & need experience (walk before run)
   a. MDOF liner (NIT/GFIT/ANCF/9x15 – *flight test?*)
   b. Inlet (limits potential of attenuation – validate predictions)
3) **Evaluate symmetry of acoustic directivity and add linear array in preparation for potential 9x15/14x22 WT entries.**
4) **Compare fixed arrays (10ft arc, 88” linear) to overhead array (impact of PBS farfield).**
5) Develop work flow for incorporating DART standard acoustic data into DADS.
6) Obtain limited performance op line information.
7) Establish research/operational procedures and polices.

Testing occurred in Apr, Aug 2017

DART in AAPL



Farfield Acoustic Directivity Evaluation - Background

Desire to install DART in 9x15 / 14x22 Wind Tunnel

- Pylon would be on traverse side (acoustic measurement)
- Sideline vs Circular Array (azimuthal angle)

GOAL: Show acquiring data on pylon side is acoustically acceptable

Define & Determine Farfield (ideally PBS outdoor arena to "complete")

- Acoustic farfield (based on wavelength – complex projection)
- Geometric farfield based on engine length (simple projection)

Overhead/Close-In Array comparisons and projection methodology

- OA little more into the geometric farfield but azimuthal angle variations!
- CA provides more diagnostic/research information (inlet/exhaust separation)
  - less attenuation (R,T,H, etc) & space/availability
- Geometric farfield arrays – point source EPNL calculation (not research)

GOAL: utilize CA advantages but develop methodology for projecting to farfield or determining when acquiring data in geometric farfield is required

Configurations Tested August-2017

PART II (arrays)

DATE	DGEN Config	Location	ARRAY	OTHER	THRUST
28-Apr-17	Baseline Inlet	ANCF	10ft arc - LHS	---	ON
4-Aug-17	Baseline Inlet	Near Center	10ft arc - LHS	Overhead Array	ON
7-Aug-17	Baseline Inlet	Near Center	10ft arc - LHS	Overhead Array	Locked Out
8-Aug-17	Baseline Inlet	Near Center	10ft arc - RHS	Overhead Array	Locked Out
10-Aug-17	Baseline Inlet	Near Center	Linear Array- RHS	Overhead Array	Locked Out
11-Aug-17	Baseline Inlet	Near Center	Linear Array- LHS	Overhead Array	Locked Out

STND FADEC Sweep:
30 sec

*safety restrictions limit max achievable speed with temp Lesson learned!

Point	RPMc(%)
1	idle
2	50.0%
3	60.0%
4	70.0%
5	80.0%
6	90.0%
7	92.5%
8	95.6%*
9	50.0%
10	95.6%*
11	idle

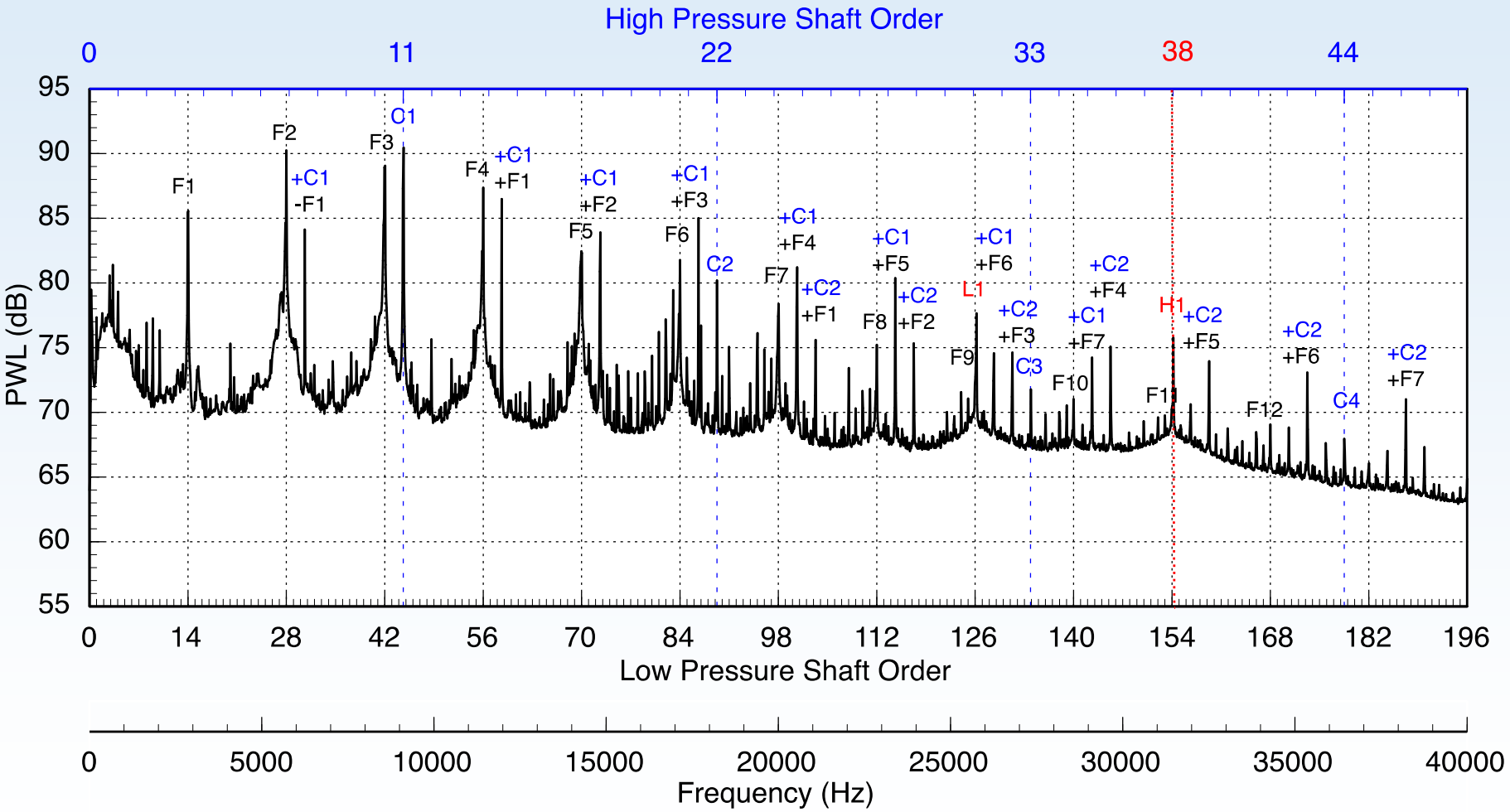
DATA Acquisition:
200 kHz @ 15 sec
BW Filter 50Hz – 50kHz

II) Baseline Data

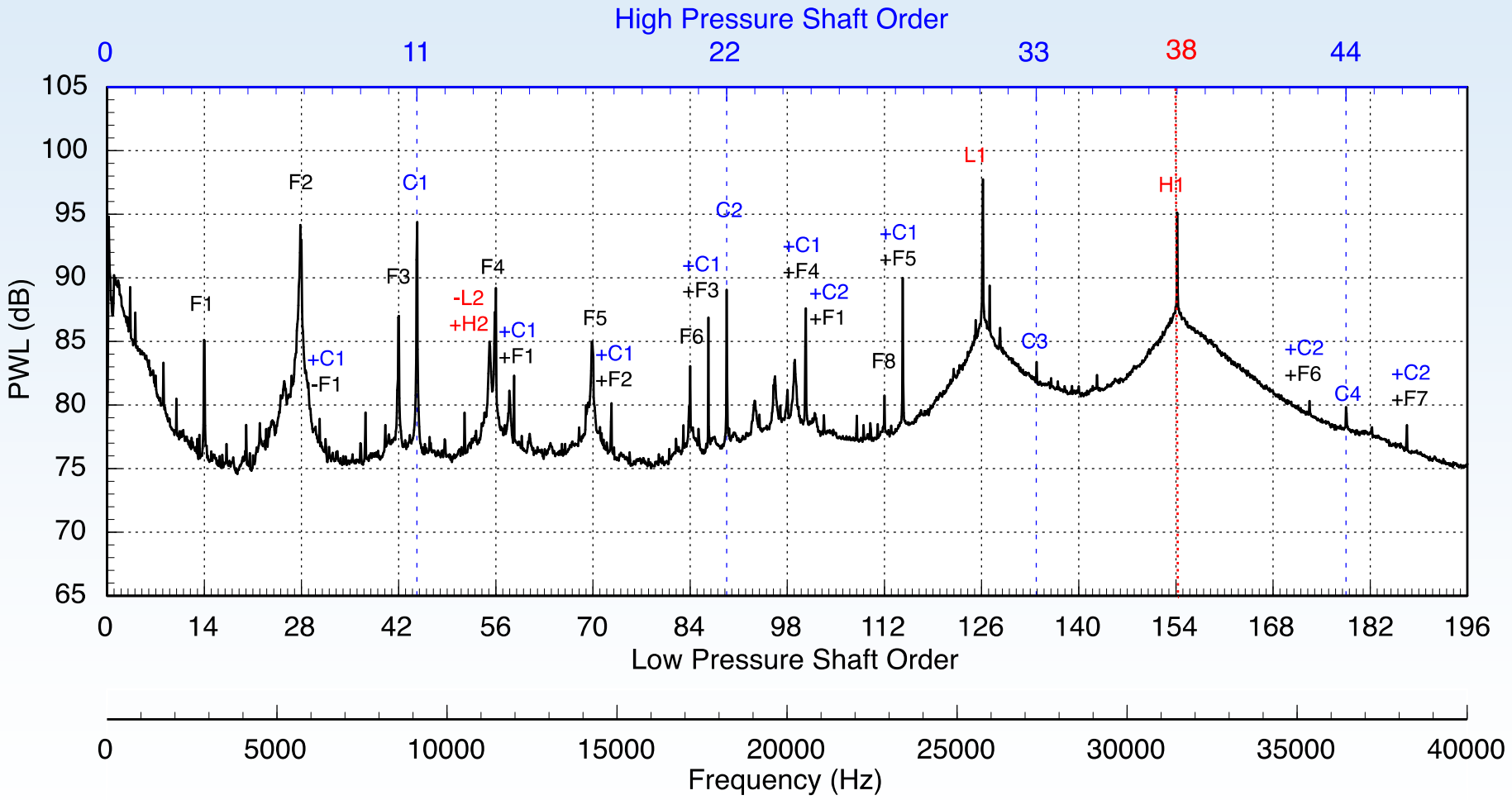
a) Spectral Content

b) Repeatability

Forward Mic Array Spectral Summation @ 92.5% RPMc-Fan

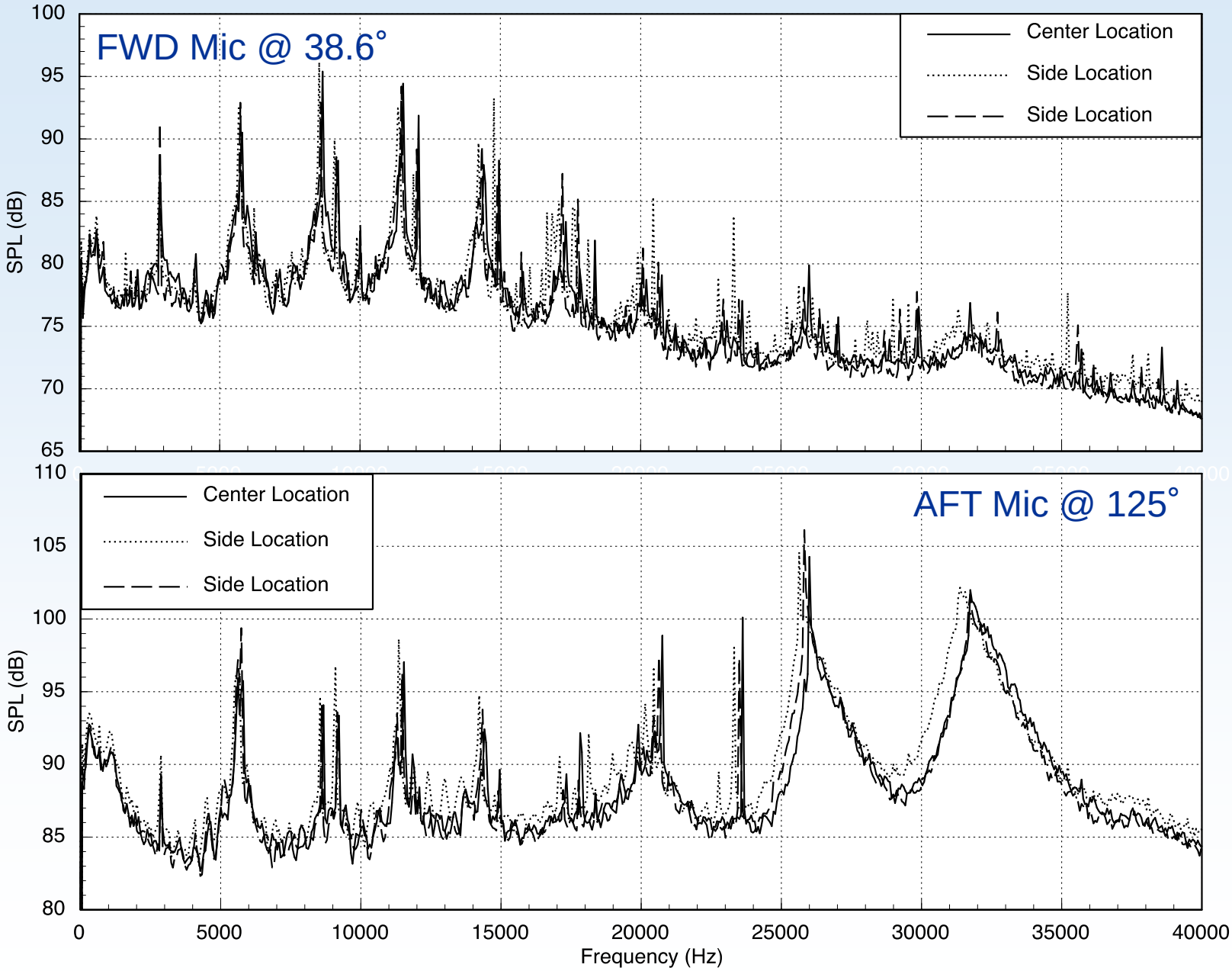


Aft Mic Array Spectral Summation @ 92.5% RPMc-Fan

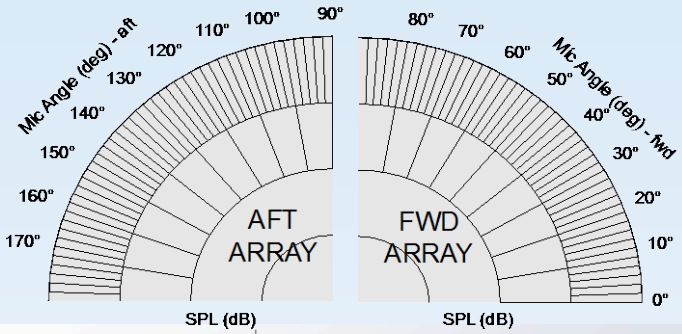


DART
DGEN AEROPROPULSION RESEARCH TURBOFAN

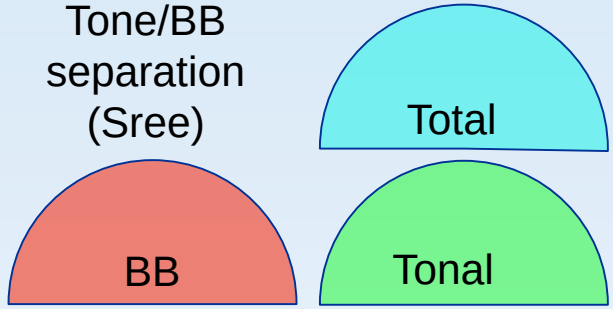
92.5% Fan-RPMc

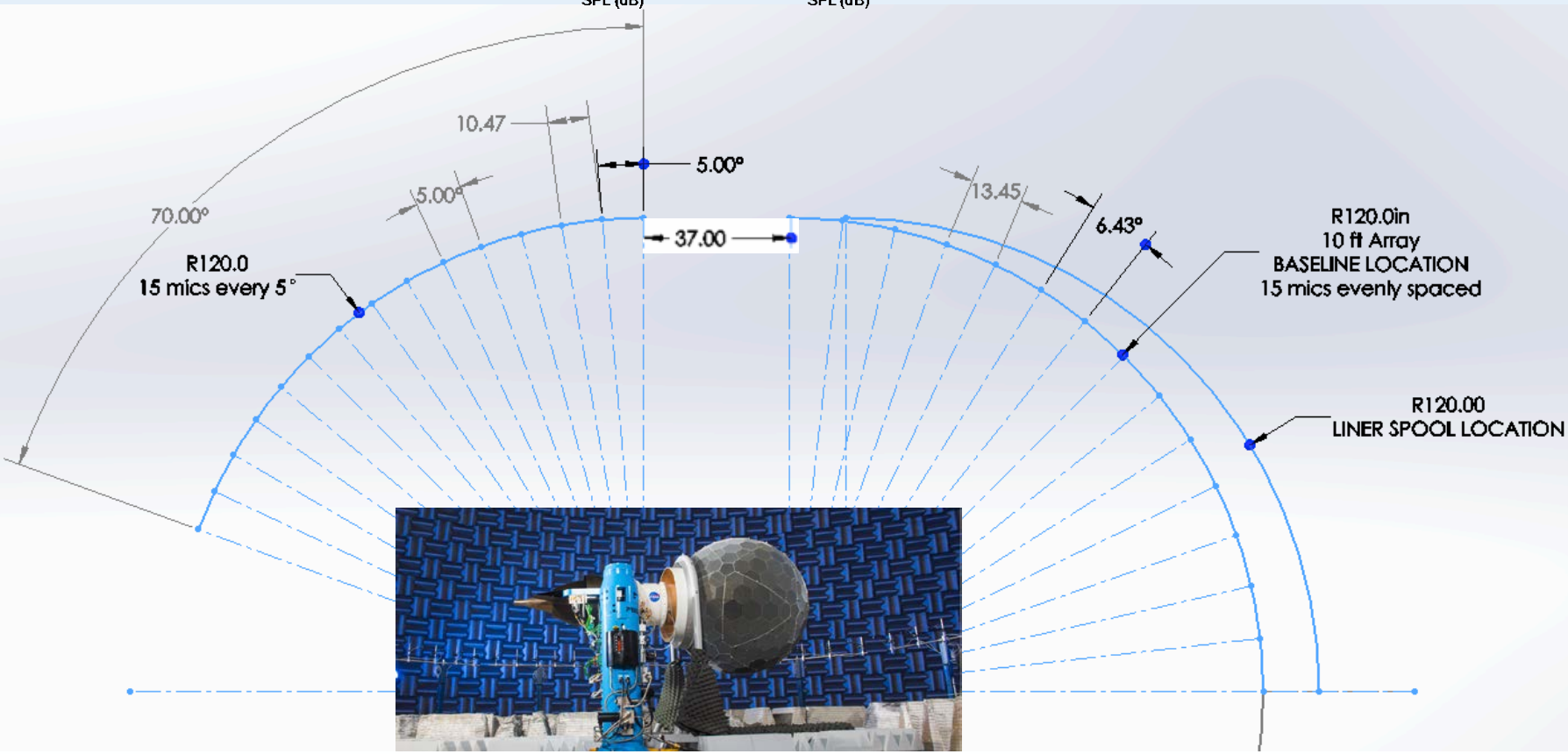


10-ft Arc Array Dimensions



Tone/BB separation (Sree)

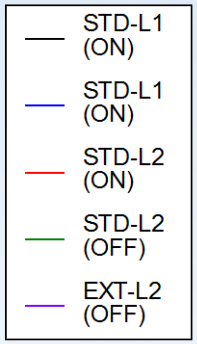


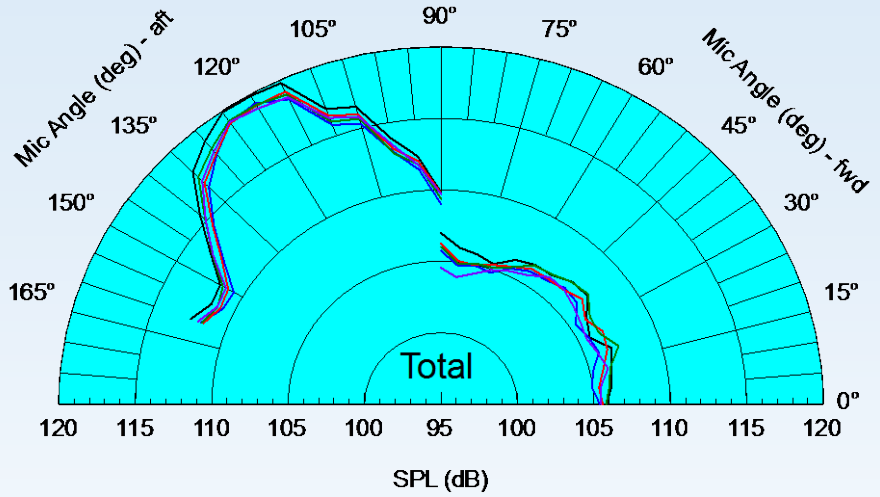


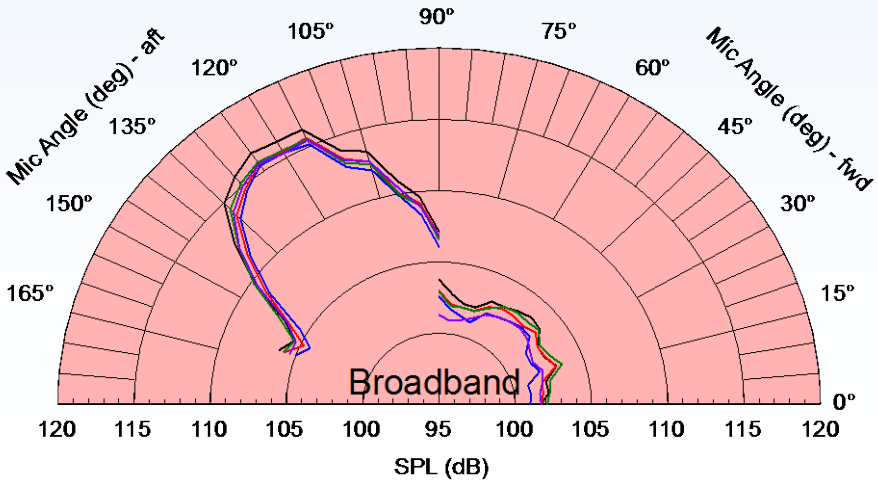
Baselines Comparison

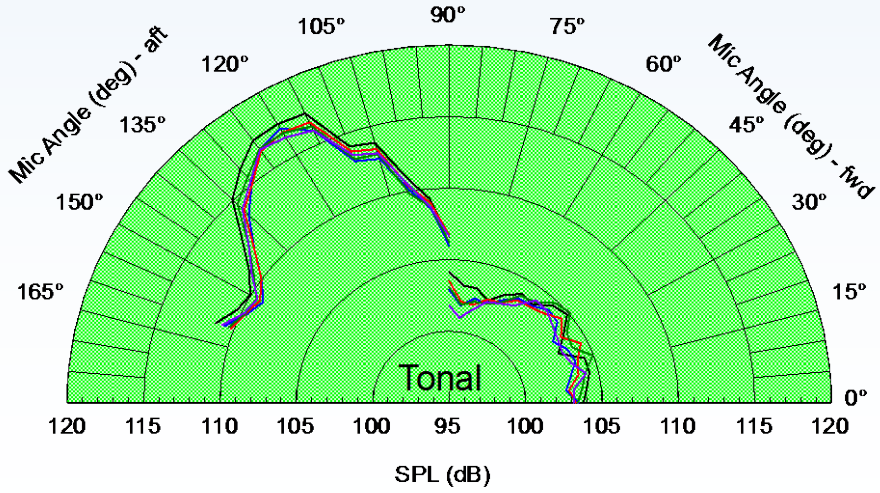
92.5% RPMc OASPL : 100 Hz to 40kHz

L1 – ANCF location
L2 – Near Center
STD – standard inlet length
EXT – Extended inlet length
ON – Pylon free
OFF – Pylon locked





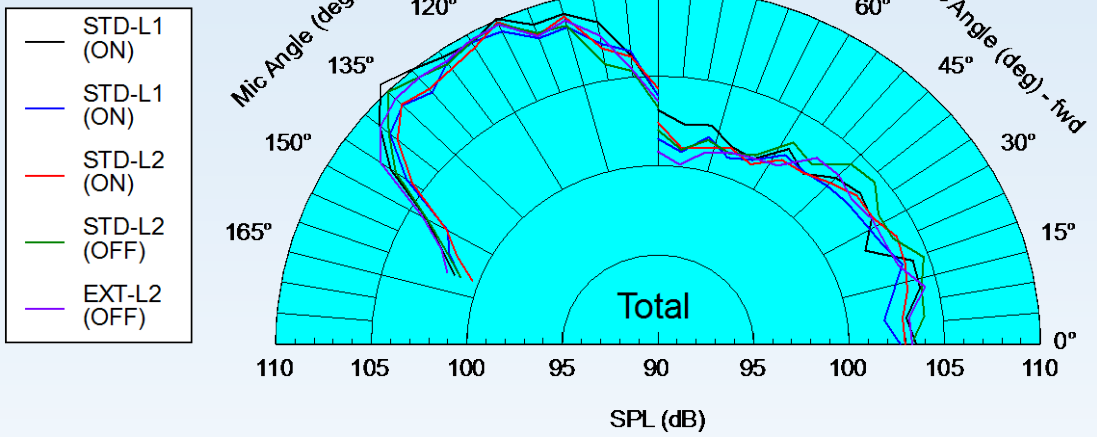


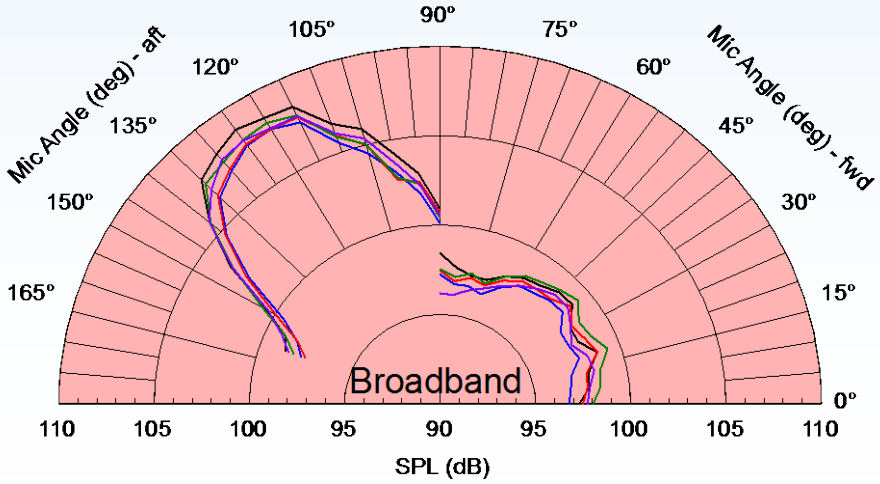


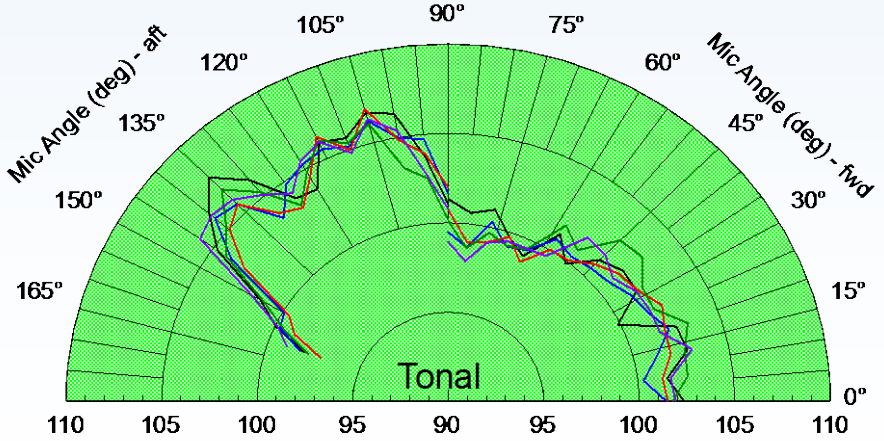
Baselines Comparison

92.5% RPMc OASPL : 1 kHz to 10 kHz

L1 – ANCF location
L2 – Near Center
STD – standard inlet length
EXT – Extended inlet length
ON – Pylon free
OFF – Pylon locked

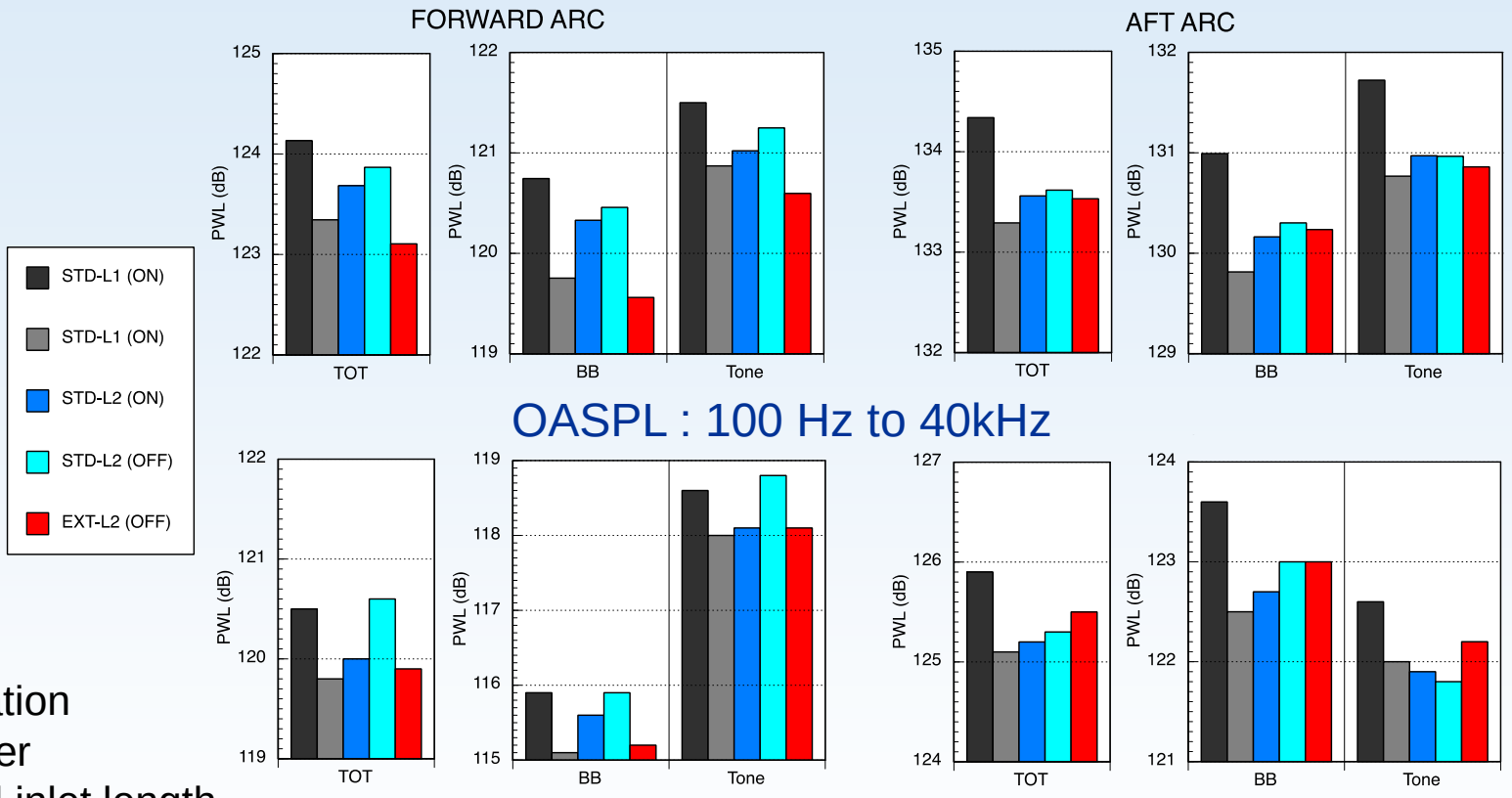






Baselines Summary Comparison

92.5% RPMc



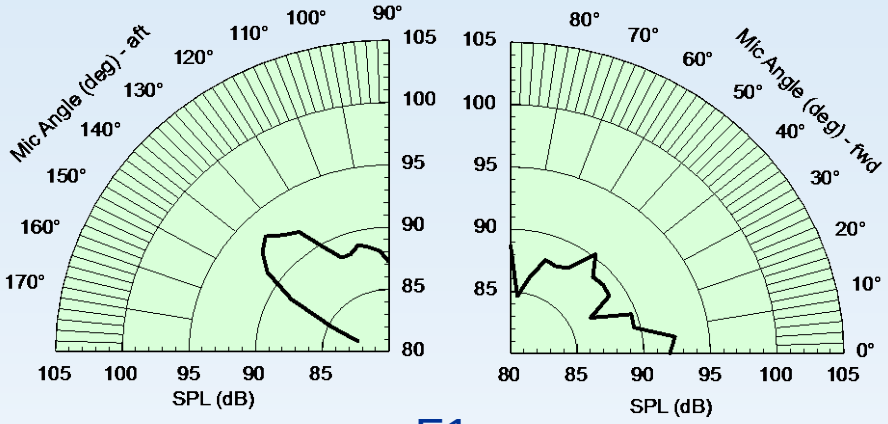
OASPL : 100 Hz to 40kHz

OASPL : 1 kHz to 10 kHz

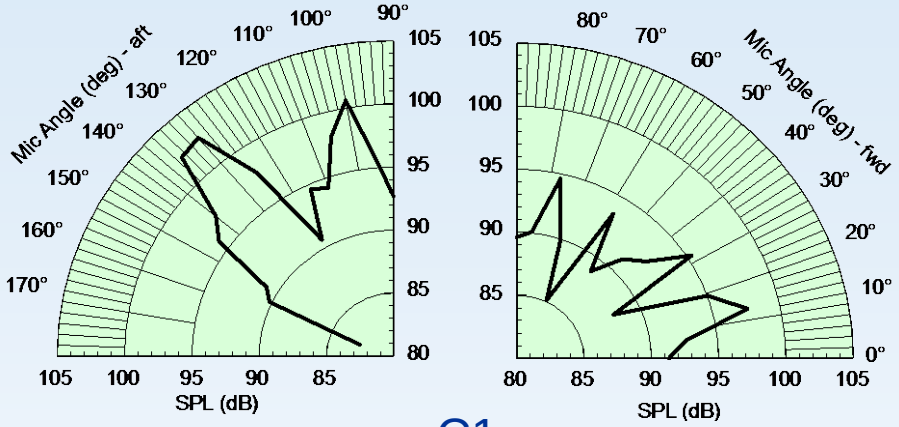
L1 – ANCF location
L2 – Near Center
STD – standard inlet length
EXT – Extended inlet length
ON – Pylon free
OFF – Pylon locked

NO CORRECTIONS APPLIED!

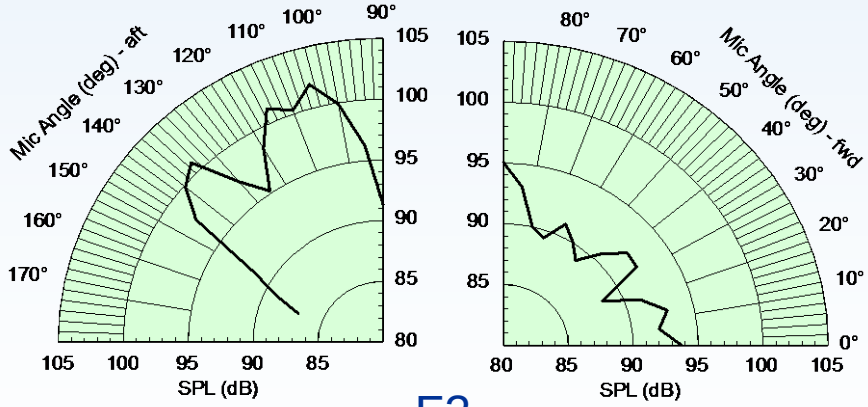
Fundamental and Harmonic Tones Directivity Isolation



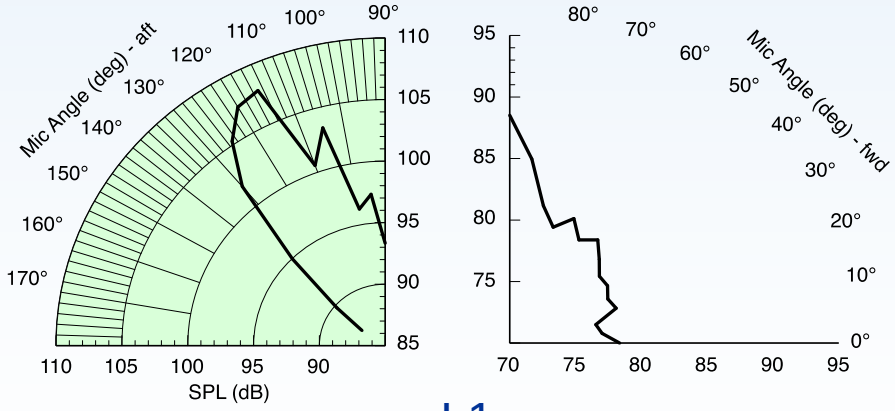
F1



C1



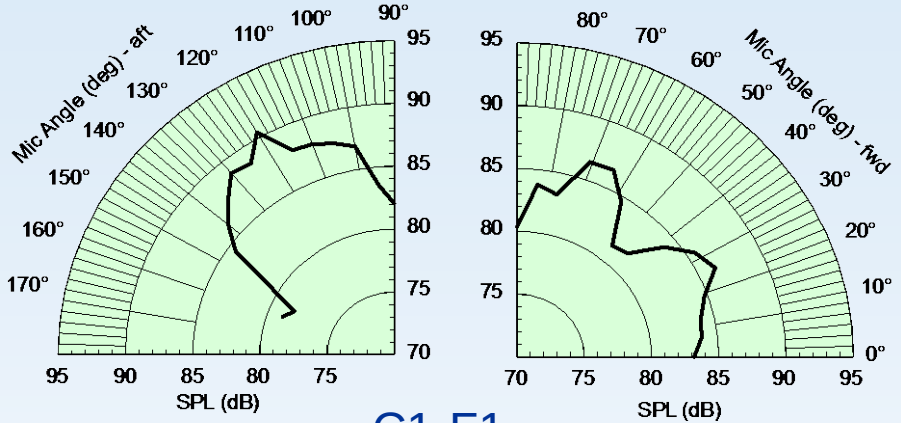
F2



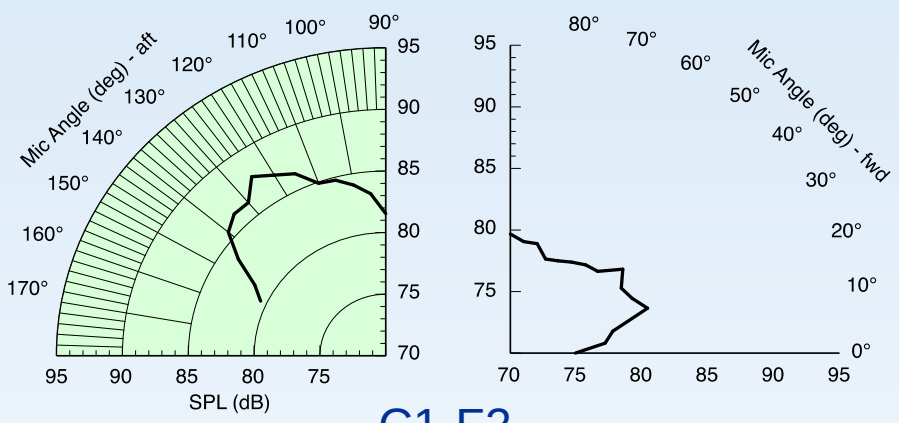
L1

(F1,F2,F3,F4,C1,C2,L1,H1)

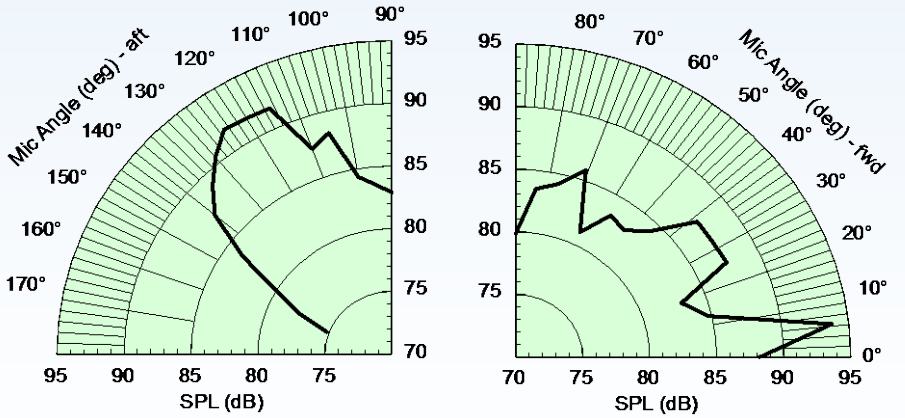
Interaction Tones Directivity Isolation



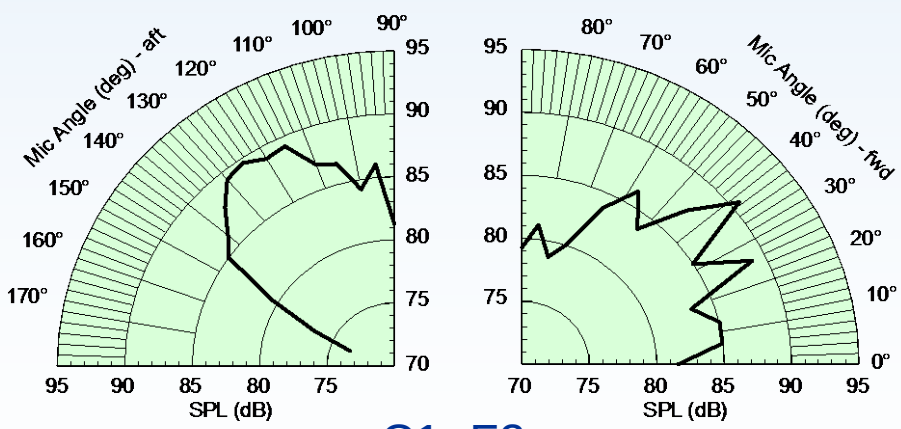
C1-F1



C1-F2



C1+F1



C1+F2

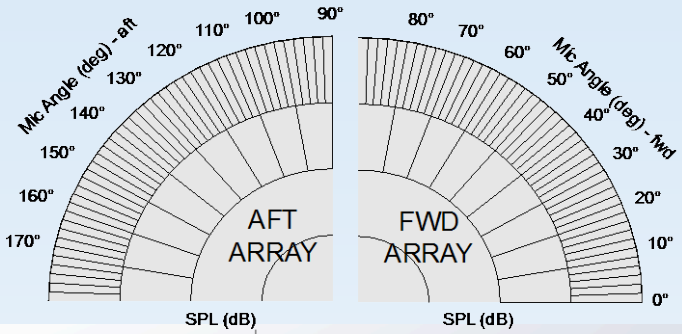
($C1^{+}/-F1$, $C1^{+}/-F2$, $C2^{+}/-F1$)

III) Symmetry

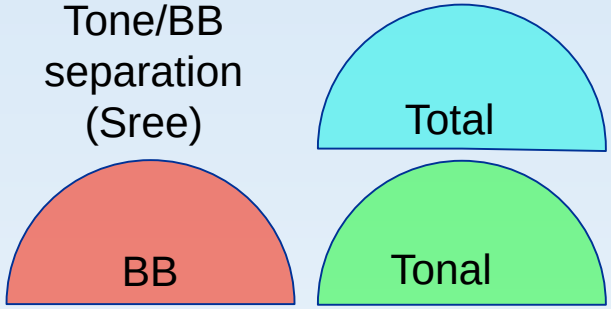
a) Circular Array

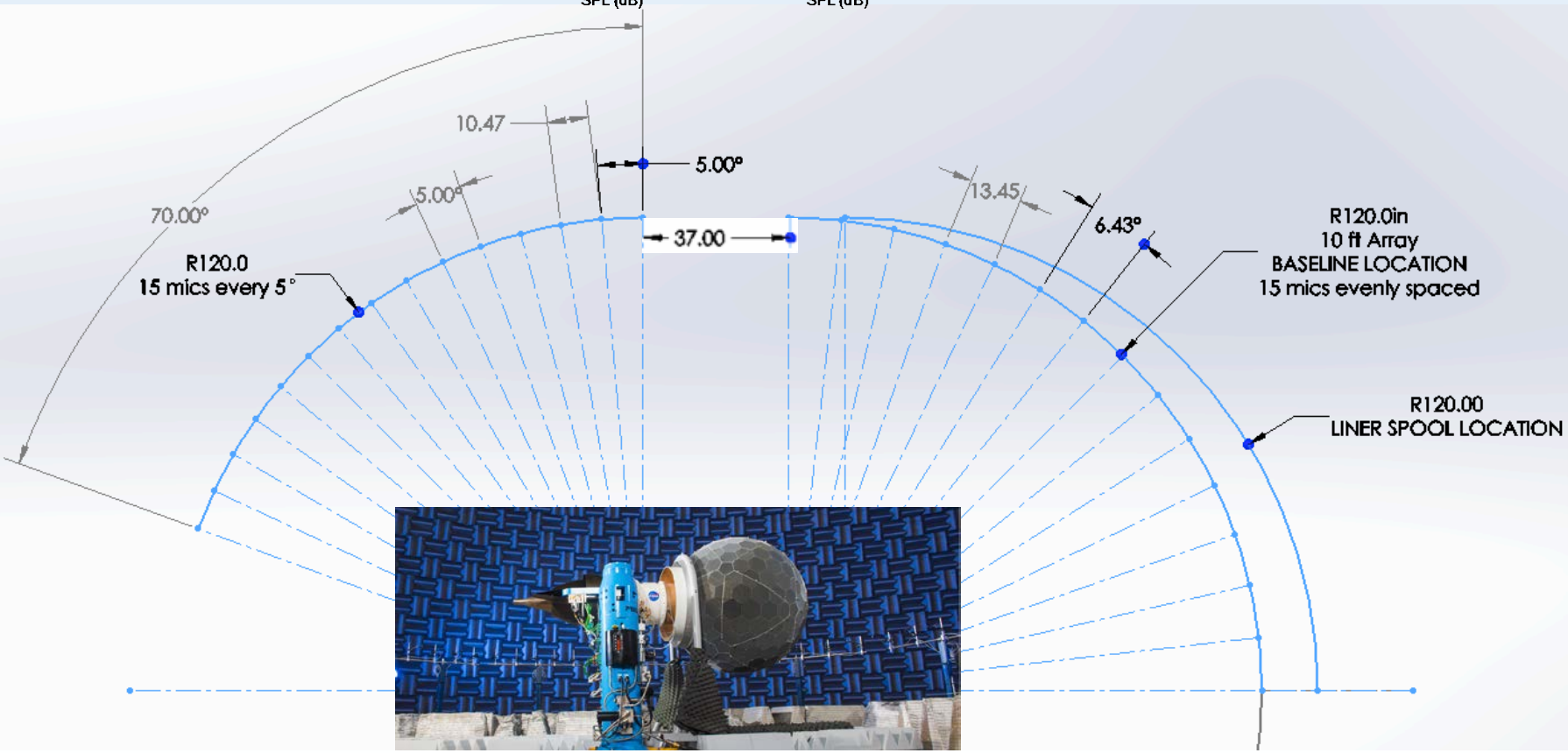
b) Linear Array

10-ft Arc Array Dimensions



Tone/BB separation (Sree)

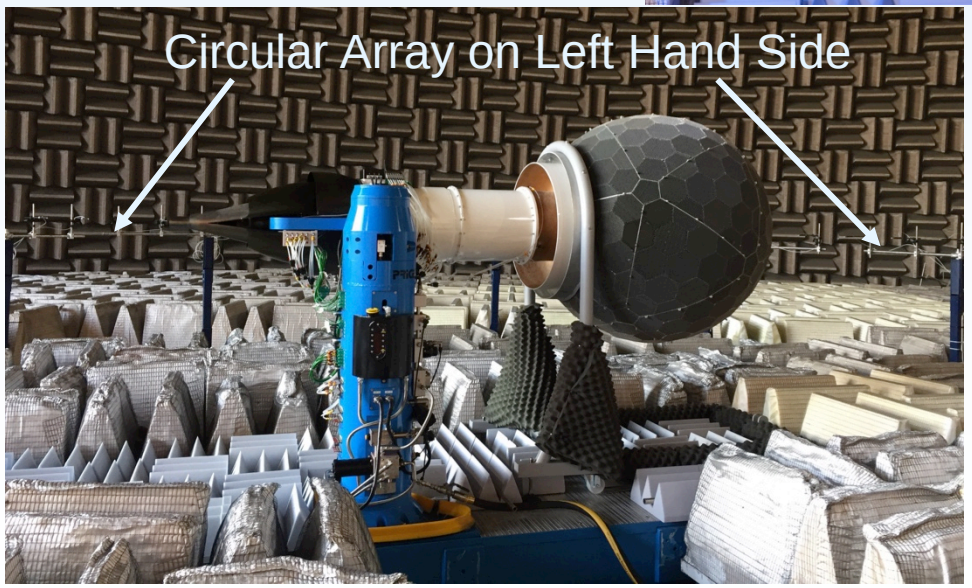




Symmetry Comparison

Left Hand Side (LHS)

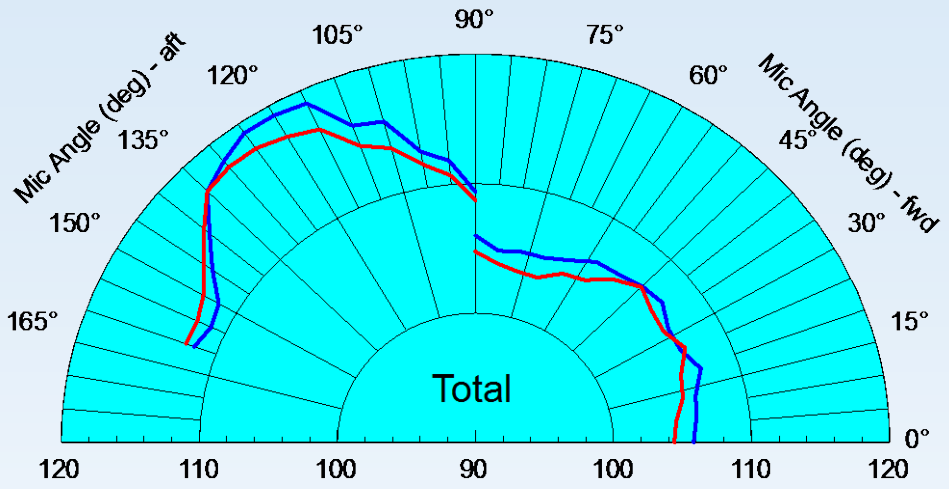
Right Hand Side (RHS)



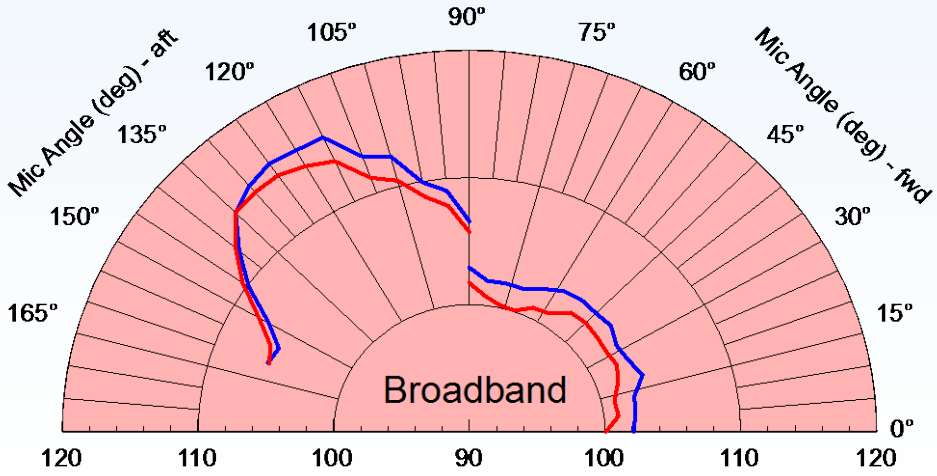
Symmetry Comparison

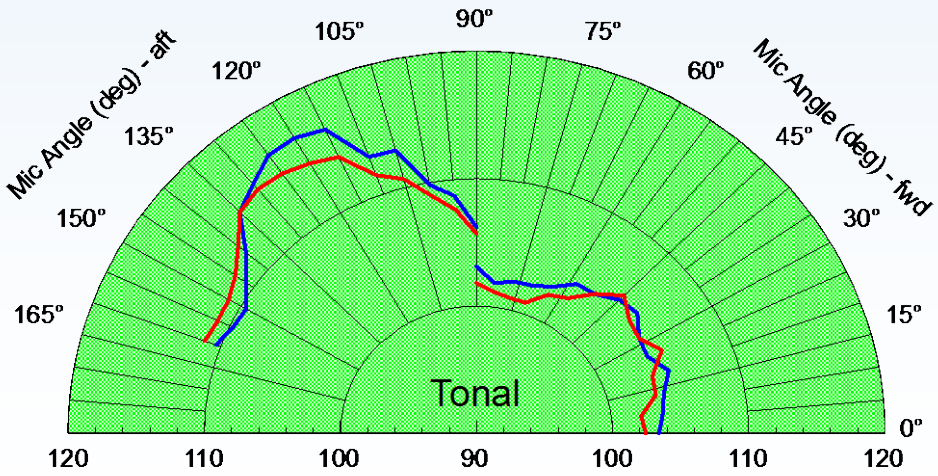
LHS

RHS



92.5% RPMc OASPL : 100 Hz to 40kHz

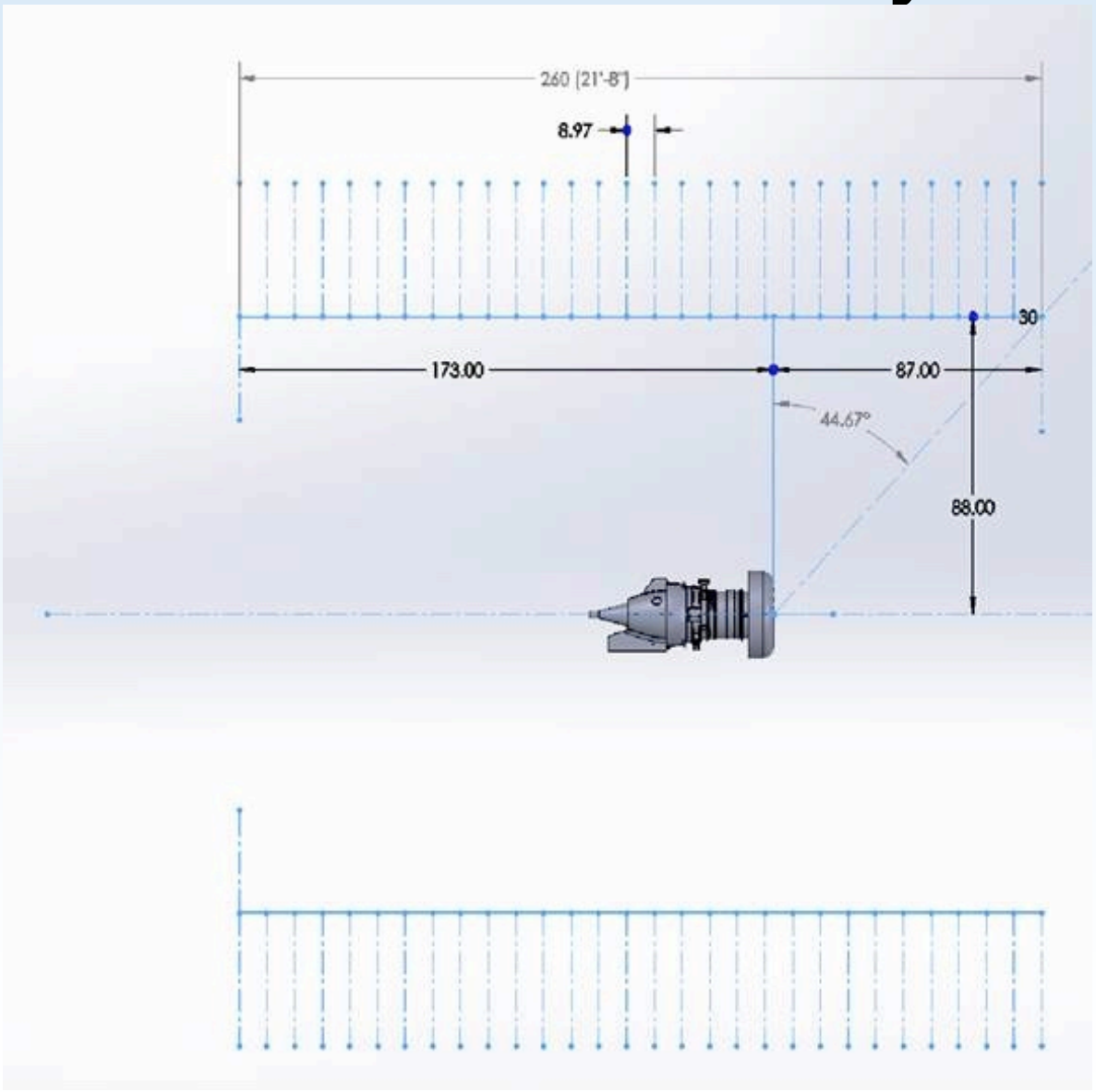




NO CORRECTIONS APPLIED!

Linear Array

(88” traverse in 9x15 WT)



Mic	Inches
1	0
2	8.97
3	17.94
4	26.91
5	35.88
6	44.85
7	53.82
8	62.79
9	71.76
10	80.73
11	89.7
12	98.67
13	107.64
14	116.61
15	125.58
16	134.55
17	143.52
18	152.49
19	161.46
20	170.43
21	179.4
22	188.37
23	197.34
24	206.31
25	215.28
26	224.25
27	233.22
28	242.19
29	251.16
30	260.13

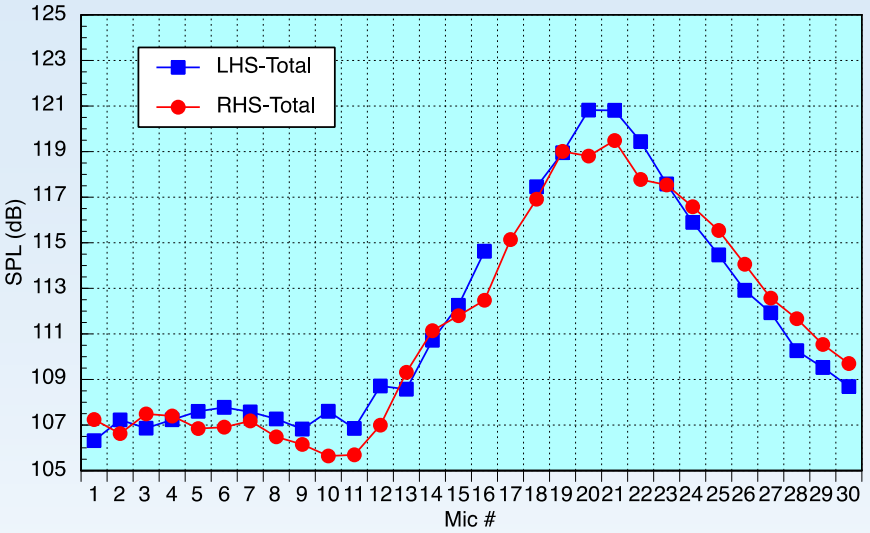
Symmetry Comparison

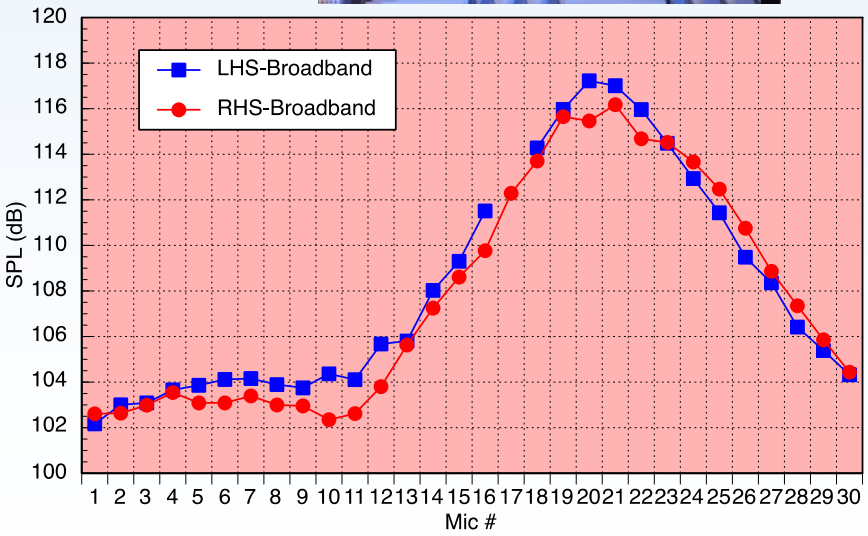
92.5% RPMc

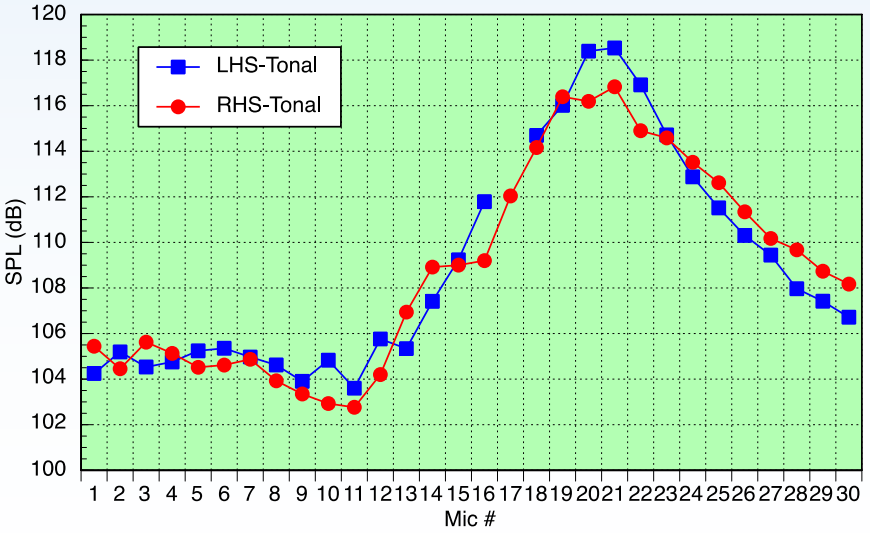
OASPL :
100 Hz to 40kHz

LHS

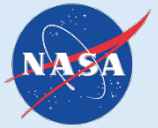
RHS







NO CORRECTIONS APPLIED! (Including R)



IV) Conclusion

Acoustic Directivity of the DGEN Aero-propulsion Research Turbofan at Multiple Farfield Array Locations

Acoustic Data Acquired from DART

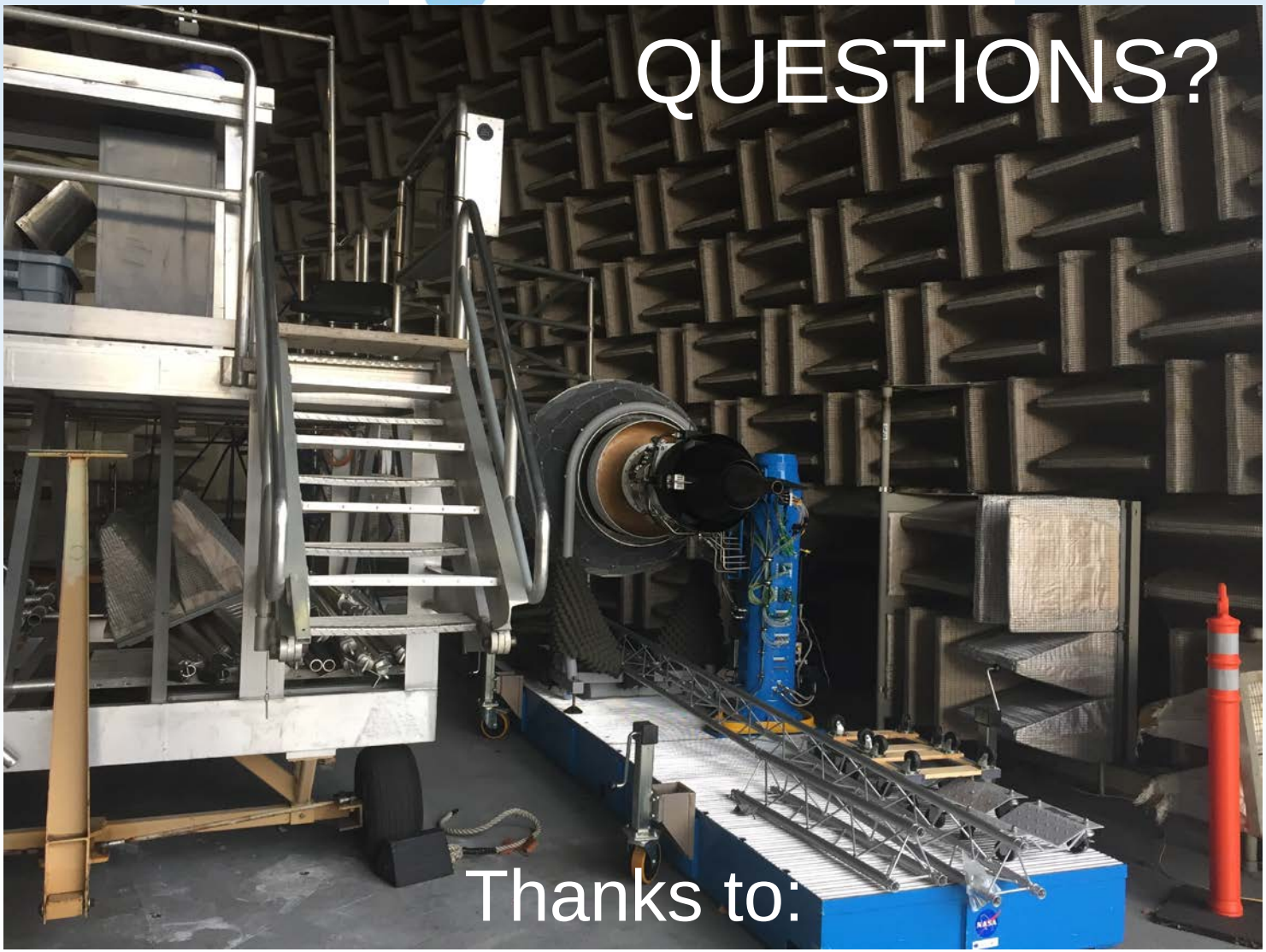
- Repeatability is typical
- Symmetry is acceptable

Companion Paper Comparisons to Overhead Array @ Location #2 – projection to a common distance.

Part of an Proposed Effort to Compare & Define Geometric/ Acoustic Farfield

- Wind Tunnel?
- Outdoor Facility?

DART
DGEN AEROPROPULSION RESEARCH TURBOFAN



Price Induction, SA & TFOME Staff @ AAPL